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How Hazardous Chemicals and Minerals Affect Workers

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Abstract

Many people use products during their daily routines, which contain different chemicals and minerals, some of which are harmful. Of the approximate 650,000 different chemicals in use today, only a handful (that are hazardous) have limits assigned (called permissible exposure limits - PEL) that indicates to boundaries of safe exposure. Still, these PEL limits were mostly calculated over 30 years ago. Has nothing changed regarding these chemicals since the 1980s? Don't we have better and faster scientific methods to test chemicals?

This paper provides some basic information regarding industrial hygiene and identifies and defines key terms and provides some insight on how to read and understand various those terms in relation to human health.

This paper also includes research on four hazardous chemicals. These four chemicals and are asbestos, beryllium, silica, and trichloroethylene.

Regarding the identified hazardous chemicals and minerals, I will discuss various topics of each including history and usage to name a few. Regarding asbestos as an example, asbestos is "A mineral fiber that can pollute air or water and cause cancer or asbestosis when inhaled" (Lee, 1992). There are materials that do not contain asbestos that can be used in its place.

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Introduction

"About 32 million workers work with and are potentially exposed to one or more chemical hazards. There are an estimated 650,000 existing chemical products and hundreds of new ones being introduced annually" (Herman, A. M. & Jeffress, C. N., 1998).

The Occupational Safety and Health Administration (OSHA) standard can be found in Title 29, Code of Federal Regulations (CFR), Part 1910.1200 (10 CFR 1910.1200). The 29 CFR 1910 Z tables provide workers with selected PELs. Approximately 500 PELs have been developed to date. Many of these chemicals are known by various names. There are as many names for these chemicals as there are uses. As the number of uses goes up, so do the number of potential hazards associated with routine exposure to these chemicals. There are many factors involved including age, general health, exposure time, etc. but in the end, exposure could result in making a person very sick up to and including death. To protect the human population and the environment from hazards, Industrial Hygiene is the profession. I will provide a section that discusses the basics of Industrial Hygiene and the federal regulations that drive it.

I reviewed data from the Centers for Disease Control and Prevention (CDC) from a database called Hazardous Substances Emergency Events Surveillance (HSEES) system. The data I reviewed was collected from 1999-2008. Unfortunately, the data I found was limited to a nine-state region, which includes (in alphabetical order) Colorado, Iowa, Minnesota, New York, North Carolina, Oregon, Texas, Washington, and Wisconsin.

The purpose of this data search was to determine if there were any health issues from incidents that involved either chemicals or hazardous minerals. The database identified just under 59,000 documented incidents where a chemical had been released. Based on the number of releases, it goes to figure that many injuries also occurred. From what I reviewed, the chemicals

that were released with the greatest number of injuries were: 1) carbon monoxide (CO), ammonia (NH_3), chlorine (Cl), hydrochloric acid (HCl), and sulfuric acid (H_2SO_4). "Carbon monoxide and ammonia by far caused the most injuries, deaths, and evacuations" (Anderson, A. R., 2015, April 10). Table 1 below identifies these chemicals and the associated injuries (Anderson, A. R., 2015, April 10).

Table 1: Number of document injuries associated with each chemical documented between 1999-2008.

Chemical Name	Number of Incidents	Number of Injuries
Carbon Monoxide (CO)	401	2364
Ammonia (NH_3)	468	1153
Chlorine (Cl)	192	763
Hydrochloric Acid (HCl)	152	326
Sulfuric Acid (H_2SO_4)	170	318

"The industry/location that had the highest percentage of injured persons involving carbon monoxide releases was other services (which includes private residences, salons, auto repair, and religious organizations … most of which occurred in private residences. The industry of real estate, rental, and leasing reported the second highest percentage of injured persons associated with carbon monoxide releases" (Anderson, A. R., 2015, April 10).

Now let's talk about the injuries that occurred that were related to ammonia. The two that received the most hits were agriculture and manufacturing. Here, the agriculture industry consisted of hunting, fishing, and forestry, while the agricultural industry consisted of textiles, apparel, along with food. Between these two industries, there was a total of 647 injuries.

"Manufacturing of paper, printing chemicals, petroleum, leather, lumber, and stone resulted in 194 (25%) of 763 injured persons associated with chlorine releases. The subsector

paper and chemical manufacturing industries had the most injured persons followed by arts, entertainment, and recreation for chlorine releases" (Anderson, A. R., 2015, April 10). "The transportation and warehousing industry and educational services represented the highest frequencies of the 326 injured persons associated with hydrochloric acid releases. Manufacturing of metal, electrical, transport, and professional and manufacturing of paper, print chemicals, petroleum, leather, lumber, and stone represented the two highest subsectors of the 318 injured persons for sulfuric acid releases" (Anderson, A. R., 2015, April 10).

This started me thinking to myself. These are all dangerous chemicals and, while I'm not routinely exposed to these compounds on a regular basis, I thought a good idea would be to explore several chemicals and/or minerals that are hazardous and research the basics. For example, what are the health effects if you are exposed to the compound, what are the target organs, are there any safe alternatives, and how can you protect yourself and others?

Hazard Communication

If some of the 650,000 known chemicals are hazardous to your health and quite possibly the environment, how are we supposed to know what is safe to use and what to avoid? As a worker myself, don't I have the right to know if the materials I'm working with are hazardous or not?

To keep the public informed regarding hazardous chemicals, OSHA maintains a standard called the Hazard Communication Standard (29 Code of Federal Regulations (CFR) Part 1910.1200), sometimes referred to as HazCom. "The standard's design is simple. Chemical manufacturers and importers must evaluate the hazards of the chemicals they produce or import. Using that information, they must then prepare labels for containers, and more detailed technical bulletins called material safety data sheets [SDS's]" (Herman, A. M., & Jeffress, C. N.

(2000). With the containers full of hazardous chemicals, there also comes the requirement for labeling the containers. Herman, A. M. & Jeffress, C. N., 2000 identifies this labeling information as "marked with the identity of the material and appropriate hazard warnings."

Employers are required to divulge, or make known, hazardous substances that exist in the workplace because of the Hazard Communication Standard. With this said, one of my questions above has been answered. With the Hazard Communication Standard, "… employers are responsible for informing employees of the hazards and the identities of workplace chemicals to which they are exposed" (Herman, A. M. & Jeffress, C. N., 1998). Yes, workers have a right to know what (if any) hazards are associated with the chemicals at their workplace they are exposed to during the course of a work day. If there are hazards associated with the chemicals they are working with, workers also need to know if there are any protective clothing available to provide them with needed protection and to keep the workers from getting sick. The Hazard Communication Standard also addresses this much-needed information. "When employees have information about the chemicals being used, they can take steps to reduce exposures, substitute less hazardous materials, and establish proper work practices. These efforts will help prevent the occurrence of work-related illnesses and injuries caused by chemicals" (Herman, A. M. & Jeffress, C. N., 2000). "The Hazard Communication Standard establishes uniform requirements to make sure that the hazards of all chemicals imported into, produced, or used in U.S. workplaces are evaluated, and that this hazard information is transmitted to affected employers and exposed employees" (Herman, A. M. & Jeffress, C. N., 1998).

I know a little bit about science from the many classes I've taken over the years. However, I'm not at all qualified to know how to test a chemical for hazardous components. One of the things the HazCom Standard does is to require the manufacturers of chemicals to test the

chemicals themselves. Companies that import chemicals are also required to do the same thing! Why do they have to do this? They are testing their own chemical products for the purpose of identifying any hazards that are associated with their products. This evaluation seems quite lengthy, but in the end, the workers or the consumers are the end users of these products. The information about the hazards from the evaluation is, in the end, provided to the workers and consumers. Manufacturers of the chemicals will provide this information in a document when the evaluation is completed in a document. This document, which is specific to the chemical, is now called a Safety Data Sheet (SDS) (formerly called a Material Safety Data Sheet – MSDS).

The SDS is a very important document because of the amount of information it provides regarding a chemical. Manufacturers, as well as the importers, are required to develop an SDS for each chemical they manufacture. Also, the SDS needs to include the specific chemical and physical properties. They must identify the individual hazards that are related to the chemical, identify each of the routes of entry that the chemical could enter the body, identify what are the appropriate actions to take if an emergency situation develops, and what is the proper methodology to use to handle the chemical safely.

Now that an SDS has been developed for a chemical or series of chemicals at your workplace, how do you as a worker know they are there? At my place of business in Paducah, each material that is used on-site has an SDS, or it cannot be used. There are no exceptions to this rule. Also, before being used on-site, the chemical must be reviewed and approved by the Safety Department. The SDS forms are all cataloged by one specific group and copies are available upon request for any worker. Also, a web page has been set up specifically to allow workers to have immediate access to this information.

Employers are each responsible for capturing and maintaining a list of their hazardous chemicals in accordance with the Hazard Communication Standard. “Copies of the [SDS] for hazardous chemicals in a given worksite are to be readily accessible to employees in that area. As a source of detailed information on hazards, they must be readily available to workers during each workshift” (Herman, A. M. & Jeffress, C. N., 1998).

My current and most recent employers each have had a way to communicate hazards to the employees and have maintained a hazard communication program. The Hazard Communication Standard requires the employers to maintain a certain amount of information regarding each chemical. Once this information has been prepared and organized, this information will follow the chemical where ever it goes. The Hazard Communication Standard requires specific types of information be maintained regarding the chemicals. This will include not only the identification of the physical hazards information (e.g., the chemical’s flammability) but also identification of any associated health hazards.

There are other things required by the Hazard Communication Standard including the requirement for employers to provide training to their employees and provide an “information program” to each of their employees who perform routine work around the hazardous chemicals and are thus exposed often during their daily tasks. This training is not limited to just the experienced workers. Company new hires will also receive this training right alongside the experienced workers. These training sessions pass along much information. Here, employers discuss multiple subjects with the employees. This includes what requirements make up the hazard communication standard. Still other topics include a discussion of the hazard communication program, what and where are the specific work operations in the company’s work area where the hazardous chemicals are being used, where the employees can find the

procedures appropriate to using the chemicals, copies of the SDS forms, and a list of the individual hazardous chemicals.

OSHA Pub 3084 identifies many items that will be included in the training program provided by employers including the following; “How the hazard communication program is implemented in that workplace, how to read and interpret information on labels and the MSDS, and how employees can obtain and use the available hazard information. The hazards of the chemicals in the work area. (The hazards may be discussed by individual chemical or by hazard categories such as flammability). Measures employees can take to protect themselves from the hazards. Specific procedures put into effect by the employer to provide protection such as engineering controls, work practices, and the use of personal protective equipment (PPE). Methods and observations -- such as visual appearance or smell -- workers can use to detect the presence of a hazardous chemical to which they may be exposed” (Herman, A. M. & Jeffress, C. N., 1998).

Trade secrets, as well as labeling information, are also covered in the Hazard Communication Program. In the business of manufacturing chemicals, trade secrets include mostly the formulas of the chemicals and process data. Specific information that includes the chemical’s CAS number would also be considered a trade secret. “The standard strikes a balance between the need to protect exposed employees and the employer's need to maintain the confidentiality of a bona fide trade secret. This is achieved by providing for limited disclosure to health professionals who are furnishing medical or other occupational health services to exposed employees, employees and their designated representatives, under specified conditions of need and confidentiality” (Herman, A. M. & Jeffress, C. N., 1998).

What if there was a medical emergency involving a chemical? When there is a medical emergency, the manufacturer of the chemical must tell the medical staff any needed information regarding the product. We have to remember that patient care has top priority. If not, how could the proper care be provided? Let's not forget the people, who import the chemicals. They are also responsible for the same as above. In an emergency situation, if the medical staff needs information about a chemical to aid in the proper treatment of a patient, it must be provided. Again, if all the needed information is not provided when requested during an emergency, then the health of the patient may be at risk, and that's not a place I want to go!

Hazardous Communication Revised!

While the original hazard communication material made much important information available to workers, it was not without its problems. MSDS's, while available for hazardous chemicals, were basically up to the individual companies to determine the content and format. What do I include and what do I leave out? Company "A" may prepare their MSDS's differently than Company "B." Further, both companies would use different formats, different labeling, and different levels of detail. This isn't complicated, is it?

Well, along came the Globally Harmonized System. Folks in the United Nations, working with people (experts) from many different countries, developed and approved the Globally Harmonized System (GHS) in the early 2000s. This GHS is a new system for classifying and labeling hazardous chemicals. It also contains many different criteria (including health, physical, and environmental classifications of hazards) that are associated with chemicals. With the new GHS, we also have a new labeling system. As stated earlier, labeling was previously required; however, there was little in the way of consistency in labeling. Now, with

the new GHS, there is specific information required to be included on hazardous chemical labels, and further, it is to be included on the safety data sheets as well!

While this all sounds like a great idea (e.g., what information was once left up to the individual manufacturers is now specified), this didn't happen quickly in the United States. It was in late 2009 when OSHA published a rule change proposal to bring the then-current Hazard Communication program into compliance with the GHS.

In early 2012, the revised OSHA Hazard Communication Standard was published, and there were two substantial changes. First of all, remember the original a material safety data sheet. It was more of a process, and little was defined or formalized. Here, the many different chemical manufacturers used their own variation. Some MSDS's provided good information, and some did not. What a way to do business! This haphazard system would be replaced with a standardized safety data sheet format. Each chemical and each mineral would utilize the new system. This would bring about some consistency that had been missing under the old system. The second substantial change would take us to a new labeling system that would be standardized. Basically, the information on the labels would each be organized in the same format making it easier to understand the hazards. As in the above change, each chemical manufacturer would participate.

Together, these two important changes would improve the understanding of the chemical hazards in the workplace.

Permissible Exposure Limits and the 29 CFR 1900 Z Tables

Seems like many if not all of the permissible exposure limits (PELs) were developed several decades ago in the early 1970s. That was back in the time when Richard Nixon was President of the United States, and the Occupational Safety and Health Act was in its infancy.

Many of the PELs that existed back then didn't adequately provide for the protection of workers, which was the goal in the first place. Back then there was a section of the act which permitted the adoption of existing standards as being enforceable. Many of the PELs are a long-ago product of the Walsh-Healy Public Contracts Act.

Now, almost 50 years later, much has changed. Not only is technology 50 years older and 50 years better but we also have 50 years of additional working experience with hazardous chemicals. All this said, the PELs from the early 1970s probably don't offer workers the needed protection, which was stated earlier.

There are three Z-Tables contained in 29 CFR 1900, and each contains their own requirements. Table Z-1 identifies the air contaminant limits and was derived from the American Conference of Industrial Hygienists (ACGIH). Table Z-2 identifies the PELs came from the American National Standards Institute (ANSI). Finally, Table Z-3 identifies mineral dust limits for the various forms of silica.

This paper will focus on four hazardous chemicals and minerals. Specifically, I will discuss asbestos, beryllium, silica, and trichloroethylene. Regarding these four hazardous chemicals/minerals, I have included a series of tables below which identifies the Z-1 (Table 2), Z-2 (Table 3), and Z-3 (Table 4) properties of each.

Table 2: Annotated Table Z-1 Values

Name of Substance	**CAS No.**	**Regulatory Limits**			**Recommended Limits**
		OSHA PEL		Cal/OSHA PEL *(as of 12/19/2016)*	NIOSH REL *(as of 7/7/16)*
		ppm	mg/m	8-hour TWA (ST) STEL (C) Ceiling	Up to 10-hour TWA (ST) STEL (C) Ceiling

Asbestos	Varies with compound	NA	NA	Refer to Section 5208	Ca 0.1 f/cm^3
Beryllium	7440-41-7	See Annotated Z-2		See Annotated Z-2	
Silica, crystalline, respirable dust	14464-46-1 14808-60-7 1317-95-9 15468-32-3	NA	NA	0.05 mg/m^3	Ca 0.05 mg/m^3
Trichloroethylene	79-01-6	See Annotated Z-2		See Annotated Z-2	

Table 3: Values from Table Z-2

Name of Substance	**8-hour time weighted average**	**Acceptable Ceiling Concentration**	**Acceptable ceiling conc. (8-hour shift)**	
			Concentration	**Max. Duration**
Asbestos	Not listed			
Beryllium	2 μg/m3	5 μg/m3	25 μg/m3	30 minutes
Silica	Not listed			
Trichloroethylene	100 ppm	200 ppm	300 ppm	5 minutes in any 2-hours

Table 4: Values from Table Z-3

Name of Substance	**Millions of Particles Per Cubic Foot of Air**	**mg/m3**
Silica – quartz	250	10 mg/m^3
Less than 1% crystalline silica (mica, soapstone, talc)	20	NA
Portland cement	50	NA

Graphite	15	NA
Total dust	50	15 mg/m^3

Industrial Hygiene

"Industrial Hygiene is a science and art devoted to the anticipation, recognition, evaluation, prevention, and control of those environmental factors or stresses arising in or from the workplace which may cause sickness, impaired health and wellbeing, or significant discomfort among workers or among citizens of the community" (Discover Industrial Hygiene, n.d.). Burgess, 1995 further defines industrial hygiene as "Occupational or industrial hygiene has commonly been defined as the recognition, evaluation, and control of occupational health hazards." That doesn't seem too hard to understand. For example, this is saying that industrial hygiene means keeping safe the workers, the environment, and the surrounding communities. Plog 1971 states that industrial hygiene is "that science and art devoted to the anticipation, recognition, evaluation, and control of those environmental factors or stresses arising in or from the workplace, which may cause sickness, impaired health, and well-being, or significant discomfort among workers or the citizens of the community." Notice is given to the word "anticipation" used in this definition!

In my neighborhood, my neighbors each have garages full chemicals and other things that are harmful when not used correctly. Some of that stuff includes herbicides to control plants, pesticides to control bugs, fuel for their gas grills, and the list goes on. Each of these products contains some sort of label with a specific set of directions on how to use the products safely. Since I started working at the former Paducah Gaseous Diffusion Plant, I have started to pay more attention to those labels and the warning they contain.

One day in particular during the Fall of 2016, I went into the garage to get into my car to drive to work. When I opened the door to the garage, the garage reeked of the smell of gasoline. I

immediately got my father, and he opened the garage door to vent without pushing the garage door opener button. We tore the garage apart that morning looking for the source before we finally found the cause. A fuel line in our push lawn mower had cracked spilling out the contents onto the mower deck where the gasoline slowly evaporated during the night. We immediately moved the mower outside into the back yard where we wiped off the mower deck. We then returned to the garage and cleaned up what was left of the small gasoline spill. Fortunately, we don't have any appliances or hot water heater that is kept in the garage, or it may have been a fire response. We recognized that we had dodged a bullet and that disaster could have struck very easily. I later asked my dad why he raised the garage door manually and hadn't pushed the button on the opener. There also was a large industrial-sized fan in the garage. My dad also didn't use the fan to disperse the gasoline smell. Rather he had me use a flat box lid to manually fan the odor. In response to my question, he mentioned that since the garage had such a bad smell of gasoline, he was afraid that an electrical discharge could have occurred igniting the gasoline if he turned on the fan or pushed the garage door opener button. I should have known! All of this started from a small quarter-inch fuel line that is about 4-inches long on a push mower.

What I do know is that both he and I were late for work that morning (my dad also works at the former Paducah Gaseous Diffusion Plant) and both of us had headaches for much of the morning despite only being in the garage and breathing the fumes for only a few minutes. It took us a few minutes to move everything around and figure out what was actually leaking.

What we did was recognize the stresses the gasoline fumes caused to our bodies. "The industrial hygienist recognizes that environmental stresses may endanger life and health, accelerate the aging process, or cause significant discomfort" (Plog, 1971).

Roles of an Industrial Hygienist

The American Industrial Hygiene Association (AIHA) identifies several roles and responsibilities for an industrial hygienist. A short-list includes walking down the work space looking for both hazards and any potential hazards that may be present. Another role is to make safety recommendations. I think my dad and I got a crash course that morning. That day we took several actions to make sure this problem didn't happen again. We relocated the mower to an outside area in the back yard. The mower is out of the weather and out of the garage. We don't fill up the gas tanks in our equipment (e.g., mower, weed wacker, or hedge trimmer) anymore either. We only put enough gas in them to get the job done, and yes, we have run out of fuel many times requiring us to stop and add more fuel. The mower is still in the place we relocated it to today! It hasn't moved much, and we haven't decided to repair it or donate it.

The list of industrial hygienist roles and responsibilities I previously mentioned from the AIHA article are "investigating and examining the workplace for hazards and potential dangers, making recommendations on improving the safety of workers and the surrounding community, conducting scientific research to provide data on possible harmful conditions in the workplace, developing techniques to anticipate and control potentially dangerous situations in the workplace and the community, training and educating the community about job-related risks, advising government officials and participating in the development of regulations to ensure the health and safety of workers and their families and ensuring that workers are properly following health and safety procedures" (What is an Industrial Hygienist? (n.d.)).

There is a whole host of industries that employ industrial hygienists. The following is another short list, this time of possible employment industries for industrial hygienists. They work in chemical manufacturing, government, insurance (sounds like a liability issue here),

unions, public utilities, laboratories, consulting firms, colleges and universities, health care and companies or cities that deal with the handling of hazardous waste.

Basically, with this list, it looks like the field is wide open for those seeking a career in industrial hygiene. I would have thought six months ago that there were very few industries that would employ an industrial hygienist. This list; however, includes public, private, as well as governmental contractors!

What Do All the Terms and Numbers Mean?

As stated previously, there are approximately 650,000 chemicals in use today. Digging down deeper still, many of these chemicals will have their own formula. As with many chemicals, there will be a long list of hazards and potential hazards. If the reader is going to understand hazardous chemicals and minerals, there needs to be an understanding of the terminology involved. For example, Chemical Abstract Services, time-weighted averages, immediately dangerous to life or health, and permissible exposure limit. Each of these, in turn, have specific numbers assigned which relate to their individual chemical properties, physical properties, and health hazards. But what does each mean? Are the high numbers always hazardous and the low numbers okay?

Each of these and other terms deserves an explanation in this paper. I started by reviewing a few of the chemicals and minerals at random using the National Institute for Occupational Safety and Health (NIOSH) Pocket Guide to Chemical Hazards. I also took a look at the numbers associated with the chemicals and minerals. In the following paragraphs, I have tried to include a brief description of each.

First, the NIOSH Pocket Guide to Chemical Hazards provides a lot of meaningful information. What I saw in the NIOSH pocket guide book were lots of chemical formulas,

Chemical Abstract Service (CAS) numbers, and chemical and physical properties. I have included a description of many of these terms, but this is not meant to be an all-inclusive list of the types of information that can be found in the NIOSH pocket guide book. Also, the NIOSH pocket guide book uses many abbreviations and acronyms. Having a reasonable understanding of the terms, abbreviations, and acronyms used in the guide book will allow the reader to feel more contented with the information.

First, the NIOSH pocket guide book initially lists the name of the chemical or mineral in question. They are listed alphabetically throughout the guide book. Chemical Abstract Services numbers are also included. This number is a unique number assigned to each chemical or mineral. The purpose is to provide someone with an easy way of searching for information in data bases. This number will definitely be helpful for the reader if he or she needs additional information about a chemical or mineral.

United States Department of Transportation (DOT) Identification and Guide numbers are also included in the table. If a chemical or a mineral has a four-digit number listed, the reader will know it is regulated by the DOT. Again, it is the four-digit number. In other cases, there may be a three-digit number included. In this case, the three-digit number is in regards to the appropriate guide number where the reader will find a series of action steps needed to stabilize the material in case an emergency situation has developed. These guide numbers will correspond to a different guidebook called the Emergency Response Guidebook. For example, I randomly selected chlorine and read through this chemical in the NIOSH pocket guide book. This chemical lists a four-digit number (1017) indicating it is regulated by the United States Department of Transportation. A three-digit code is also included (124) for chlorine indicating there are emergency steps included in the Emergency Response Guidebook regarding this chemical in

case of an emergency. I; however, did not research the Emergency Response Guidebook regarding the emergency steps.

The NIOSH pocket guide book lists many chemicals that have multiple names. These chemicals, although they are referred to by different names, have the same formulas. The NIOSH pocket guide book contains a section identifying the many different trade names as well as chemical synonyms. Knowing that a chemical or mineral is called by different names certainly is something one would want to know. What if you have a chemical and you're reading the label, and you don't recognize any of the names? Knowing there may be multiple names for a chemical would be helpful in this case. As an example, hydrochloric acid (HCL) is also known as muriatic acid. Methyl ethyl ketone, which is a solvent, is also known as 2-butanone. The guide book identifies this.

Exposure Limit Terms

In a nut shell, exposure limits for a chemical or mineral are the upper limits that a worker can work in safely without expecting any harmful effects. Exposure limits are typically expressed in concentrations. For example, parts per million (ppm), milligrams per cubic meter (mg/m^3) and occasionally in micrograms per cubic meter ($\mu g/m^3$). As an example, if you have 50 ppm of automobile exhaust, that means you have 50 parts of automobile exhaust for every 1 million parts of air.

The NIOSH pocket guide book makes a reference to the recommended exposure limit (REL). These numbers are the recommended exposure limits made by NIOSH. The REL is a level that NIOSH states should not be exceeded and is a time-weighted average (TWA) concentration up to a maximum of 10 hours. These are provided as an average. This means that

exposure to the hazardous chemical can be higher than the limit but for part of the day only. This implies that the exposure is also lower for part of the day, thus an average.

Long-term exposure is related to TWA. The understanding here is that a worker will not become ill if he or she works at a job in an area up with concentrations up to this level. However, above that concentration for an extended period of time is a different question altogether. The extended period is typically making a reference to an eight-hour shift, which, in turn, covers a 40-hour work week over a total of five days. In simple terms, the expectation is this: I should be able to work under these conditions all my life, and if the concentration levels don't go up any higher, then I won't get sick, and I won't have any health problems as a result.

When the REL is used along engineering controls and personal protective equipment (PPE) as an example, NIOSH is saying this exposure level is a safe level for workers.

Compare this to the short-term exposure limit (STEL). This is rather interesting as it represents an exposure period of a maximum of 15-minutes. In this case, if a worker is performing a task using a chemical that has an assigned STEL, 15 minutes is your limit! After that period, if the worker is still exposed to that chemical, then the worker could be in danger.

Another limit that is referenced in the NIOSH pocket guide book is the ceiling limit (C). This limit is an indicator that the chemical or mineral has the intent of acting fast. Here, if a chemical is being used that also has a ceiling limit, the worker may need to re-think how to get the work completed. The ceiling level is a limit that should not be exceeded at any time during any work day.

Another acronym used in the NIOSH pocket guide book is permissible exposure limit (PEL). We have discussed the PEL briefly in one of the earlier sections. The PEL is a limit that is enforced by OSHA. The PEL mean that value which is the maximum exposure limit of an

employee to a chemical. The permissible exposure limit (PEL) is “an exposure limit that is published and enforced by OSHA as a legal standard” (Plog, 1971). It sounds to me like the PEL limits represent the law and cannot be exceeded. As I stated in one of the earlier sections, the limits for chemicals are typically provided in parts per million (ppm) or milligrams per cubic meter (mg/m^3). “The United States Department of Labor’s Occupational Safety and Health Administration (OSHA) adapted the [threshold limit value – TLV] list in its first attempt to provide legal control of the work environment by making the guides mandatory. These were then called Permissible Exposure Limits” (Plog, 1971, p. 394). The American Conference of Governmental Industrial Hygienists (ACGIH) is a group of scientists (among other things) that established the threshold limit values. These values are not binding by and federal regulation.

The NIOSH pocket guide book also contains a column in the chemical table that lists the concentration level that is immediately dangerous to life or health (IDLH). This number sounds really important. I didn't read every entry in the NIOSH pocket guide book, but I didn't see any other numbers listed in this area other than the IDLH value! The NIOSH-Mine Safety and Health Administration (MSHA) approval regulations define IDLH as “Conditions that pose an immediate threat to life and health or conditions that pose an immediate threat of severe exposure to contaminants such as radioactive materials which are likely to have adverse cumulative or delayed effects on health” (Plog, 1971, p. 540). I wouldn’t want to work with a chemical in a concentration that is near the IDLH value. There must be a safety margin. There is one; the IDLH values are based on what the possible effects might be if a worker is exposed at a concentration for a 30-minute period.

Here, we see an escape clause. By using the IDLH value, a worker is thus provided with a safe way out of an area without suffering any harmful effects, assuming they get out before the 30-minute limit has been reached.

What happens if the IDLH value is exceeded? I wouldn't wait around as my 30-minute clock ticked; I'd find the fastest way out immediately! Above that level for a given hazardous chemical or mineral, the worker is at risk. At those levels for an extended period of time, it sounds like the worker and any other nearby workers need to be in a respirator or be wearing some type of breathing apparatus that will ensure that a fresh air supply is constantly available. Not much margin for error when dealing with IDLH!

There are also the lower and the upper explosive limits. The lower explosive limit (LEL) is defined as the "Lower explosive (flammable) limit in air, % by volume (at room temperature)" (Health and Human Services, 1997). This means the lowest concentration of vapor in the air below which flame will not spread if there were an ignition source.

Likewise, the upper explosive limit (UEL) is defined as the "Upper explosive (flammable) limit in air, % by volume (at room temperature)" (Health and Human Services, 1997). This sounds like the opposite of the explanation above, but UEL means the upper concentration of vapor in the air which flame will not spread if there were an ignition source.

Flash point is another value to consider. The flash point, designated as FP, is the temperature at the lowest point that a vapor will ignite (of course, in the presence of an ignition source).

If a chemical or mineral is considered to be a carcinogen in the NIOSH pocket guide book, then the substance has the designation of "Ca." I don't think there are any safe exposure levels for any chemicals or minerals that are considered a carcinogen. The best thing to do here is

not use that substance at all and find something else as there is no guarantee you won't get cancer.

There is a section in the NIOSH pocket guide book that discusses some very simple but important information. This is the section that discusses sanitation and personal protection. I would liken this section to something titled "Best Management Practices" as it makes general recommendations throughout regarding such things as eating, eye protection, and washing hands.

In order for a hazardous chemical or mineral to be harmful, it must first find a way to get into your body. Chemicals seem to have many ways to cause problems. First, they can irritate the skin or even burn the skin, while some others may resort to irritating the eyes or possibly burning the eyes. Neither of these two sounds like a great thing as you could easily end up with damaged skin or eyes. I've learned through the years to be real careful around anything that can damage my eyes if mishandled! Irritation of the eyes could lead to something called conjunctivitis. This is when the eye membrane gets inflamed. Irritation of the skin on the flip side could lead to dermatitis. That's skin inflammation. Also, workers need to be real careful working around acids! Here, you could get burnt to either the skin or the eyes with contact with acids. Also, the burns could be the result of contact with either the liquid form or vapor form (contact is not limited to liquids alone). I know people think mostly of the liquid form when they think getting burned but it could also be the vapor!

There are several options for a hazardous chemical or mineral to enter the body. A few examples of these are inhalation, absorption or contact with the skin, ingestion, and injection.

"Chemical compounds in the form of liquids, gases, mists, dusts, fumes, and vapors can cause problems by inhalation (breathing), absorption (through direct contact with the skin), or ingestion (eating or drinking)" (Plog, 1971, p. 17).

The basics of the lungs are pretty easy to understand in that they are used to breathe and take in air. The lungs, in turn, will release carbon dioxide. But what happens if the air we breathe includes some potentially unwanted material such as nearby fumes or dust? Inhalation of hazardous materials is recognized as the biggest threat to the health of workers. Inhalation is also the most common route of entry for dusts and fumes for the American worker. The lungs are supposed to provide a way of getting air into the body and deliver it to the places in the body that need the air, then breathing out the carbon dioxide. If the air we breathe contains unwanted dusts and fumes, they will also be delivered into the body with the air as we breathe whether we want this to happen or not.

With absorption, a chemical needs to initially come into contact with the skin first. "A material is said to have been absorbed only when it has gained entry into the blood stream and consequently may be carried to all parts of the body" (Sax, 1968). I use to think of the skin as an impenetrable surface; however, that couldn't be farther from the truth.

Ingestion is a possible route of entry for a chemical or material that involves eating and drinking. Workers don't typically intend to consume the materials they directly handle. "Ingestion is not an important route of entry, except when the acute (short-term or single dose) or chronic (long-term or repeated dose) toxicity by this route is very high" (Peterson, 1991).

Injection is another route of entry. In this manner, a hazardous material could enter the body by penetrating the skin.

Controlling Hazards

How Can Hazards be Controlled?

If you have an identified hazard in the workplace, it must be either controlled or eliminated. The health of the workers, the surrounding communities, as well as the protection of

the environment, should be first priority. This concept is pretty easy to understand. The more I can control a hazard the more protected the workers become. There are a number of directions we can go to control a hazard. Each is important in playing a role in protecting the workforce and should be considered. Some methods are better than others, but they each have their own way of getting the job done. Some are easier than others to implement while other methods provide better clout to control or correct a hazard.

From the research I have done, I see about three ways to bring a hazardous condition under control. They are engineering controls, administrative controls and Personal Protective Equipment (PPE).

These methods must be followed according to the list above with engineering controls being the top choice and PPE always being the last resort.

Engineering Controls

An engineering control is a method of controlling hazards that works well. While the hazard may still be present, this method implements a design change to control the hazard.

For example, at your workplace, you may have a pipe in the ceiling that hangs down into the walkway. While shorter people may not have any issue maybe taller people bang their heads on the pipe every time they walk by. An engineering control could be implemented here by redesigning the piping system to relocate the low hanging pipe to a safer place out of the designated walkway. With all this in mind, it sounds like the use of obstacles for hazard control should be the main choice.

Administrative Controls

In this type of control, the hazard remains; however, other methods are utilized to control the hazard. For example, a stream pipe system may not be able to be relocated without sufficient

cost and may put workers in additional danger. So what do we do in this situation? Here as an example, a procedure could be developed. A procedure could provide step by step information detailing how to safely work on the system or work in the vicinity of the steam pipe.

Personal Protective Equipment

This method seems like a last resort! You have a hazard that cannot be controlled by engineering or administrative controls; however, the workers still must be maintained safely. This type of control may involve providing workers with protective clothing appropriate to the hazard.

Below is a table that summarizes the hazard control hierarchy that is described by the Centers for Disease Control and Prevention (Hierarchy of Controls, 2015).

Table 5: Hazard Control Hierarchy

Hierarchy of Controls		
Control	**Description**	**Level of Effectiveness**
Engineering Controls	Hazard is still present, but workers are isolated from the hazard.	Effective
Administrative Controls	Hazard is still present, but policies and procedures for the way people do the work are put in place to manage the hazard.	Somewhat effective
Personal Protective Equipment	Hazard is still present, and the workers are protected by wearing personal protective equipment.	Least Effective

The controls listed at the top of the table are the most effective at controlling hazards. The types of controls are less effective as you get to the bottom of the table.

There are other ways to control hazards including properly training the workforce to recognize hazards before they become a problem, providing an early alarm or warning system in case an emergency situation arises, performing routine equipment maintenance.

These types of controlling hazards don't involve removing the hazard. Having an alarm system wouldn't remove the hazard, but it could provide a sort of early warning system for the workers. Think about it, once an alarm has activated, workers respond to address the hazardous condition. Again, the hazard remains in place; however, the workers have been provided with an early warning system to let them know that a hazard condition exists that needs immediate attention to correct. A good example of this type of hazard control is a fire sprinkler system. Once the fire starts and generates enough smoke and heat, the system will recognize this and automatically activate releasing water to put out the fire.

Training, on the other hand, provides workers with the proper tools to recognize and deal with hazards. At that point, one of the other control methods can be implemented.

Another way to control hazards is to perform proper maintenance on equipment and perform routine inspections of the equipment looking for problem. In this way, problems can be identified early and corrected before they actually become a problem. Even correctly designed equipment can eventually turn into unsafe equipment if the proper maintenance and inspections are not completed at regularly scheduled intervals. It sounds like a procedure process needs to be put in place to make sure this happens as needed! The larger and more dangerous the hazards are, the more a procedure system would be needed. Let's not forget that much of the equipment is

hazardous simply because of their size and weight. Operating as well as maintaining the equipment may also be hazardous. All this sounds like more ammunition for a procedure system!

Is a Respirator Protection Program Needed?

There is a guide in the NIOSH Pocket Guide to Chemical Hazards (U.S. Department of Health and Human Services (Ed.), 1997) that provides guidance on respirator selection for hazardous chemicals and minerals that have IDLH values assigned. "The key elements of any respiratory protection program must start with an assessment of the inhalation hazards present in the workplace" (Plog, 1971, p. 538). This sounds like a mass data gathering event! And so it should be.

First, we need to anticipate the hazardous chemicals or minerals involved. What are the hazards? Has there been any past research in the area and is there any data available that can be viewed? Maybe there are some safety-related data available. All this must be researched, gathered, and analyzed prior to the start of any work. The goal here is gaining knowledge and protecting the workers by using the knowledge you have just gained to reduce (or even eliminate) existing hazards. The OSHA methods of compliance are pretty straightforward. "The standards require the use of engineering or work-practice controls to reduce exposures to the PEL or below" (Plog, 1971, p. 538). Even after the appropriate controls have been put in place and implemented, what happens if the exposure levels don't go down to or below the PEL? That is the point where you know you need a respirator program. Respirators are a good addition to any safety and health plan for protecting worker; however, their use should not be the first choice. Rather, putting employees in respirators should be the last choice. There are other safety controls that can be used before the need arises for respirators.

A good example would be trying out a ventilation system. This type of system works to remove dust and fumes from the work area thus protecting the workers.

Federal Laws

Occupational Safety and Health Act of 1970

"The goal of an occupational health program is the maintenance and promotion of employee health and well-being by protecting employees from undesirable health effects that can result from inadequately controlled equipment, processes, materials, products, and wastes" (Plog, 1971, p. 5). Companies will have a health plan dedication to protecting the health of the workers, the neighboring communities, and the environment. All this starts with the Occupational Safety and Health Act of 1970 (OSHA). The Occupational Safety and Health Administration is the agency which that provides oversight and enforcement of the Occupational Safety and Health Act.

There is a main purpose of this act, which is to ensure a safe and healthy place to work for the workers. It was the United States Department of Labor that developed a set of safety and health-related standards. These standards included many things including exposure limits, the threshold limit values for several chemicals and minerals,

as well as training and recordkeeping requirements to name only a few. "The 1970 OSHAct has clearly defined procedures for promulgating regulations, conducting investigations for compliance, and handling availability of exposure data on workers, keeping of records, and other problems" (Plog, 1971, p. 5).

National Institute for Occupational Safety and Health (NIOSH)

OSHA needed a way to conduct research on the health effects to workers regarding exposures to hazardous chemicals and minerals in the workplace. What OSHA did was it

established an "institute" for the purpose of conducting this type of research. The National Institute for Occupational Safety and Health (NIOSH) is housed in the United States Department of Health and Human Services as part of the Centers for Disease Control and Prevention (CDC). NIOSH plays a key role in the occupational safety world. NIOSH, identified on the CDC website (About NIOSH, 2016), conducts research, promoting safe and healthy in the workplace, annually publishing a complete list of known chemicals and minerals that are known to be hazards, and working with international organizations to promote safety and health in the workplace. They also publish a pocket guide called the NIOSH Pocket Guide to Chemical Hazards (U.S. Department of Health and Human Services (Ed.), 1997), which I have made reference to earlier in this paper. This is a handy "pocket-sized" book that contains much information about hazardous chemicals and minerals.

Asbestos

What is Asbestos?

Asbestos is not actually rock. Rather, it's a mineral made up of many individual fibers. You don't want to breathe the fibers either, you want to stay as far away as possible. Asbestos is defined as, "A mineral fiber that can pollute air or water and cause cancer or asbestosis when inhaled" (Lee, 1992). One of the diseases that asbestos is responsible for is called asbestosis. Asbestosis is "a disease of the lungs caused by inhalation of fine airborne fibers of asbestos" (Plog, 1971, pg. 852). Deposits of the asbestos materials can be found all over the world in very large quantities.

Asbestos maintains some good properties and; therefore, some popular uses. If I make a product and it contains asbestos, it is strong and it resists heat. Because of its strength, I'm happy with this as a manufacturer. But asbestos comes with some inherent problems. "Asbestos fibers

are generally characterized by high tensile strength, flexibility, heat and chemical resistance, and favorable frictional properties" (Plog, 1971). Because of its many qualities, asbestos in the past has even been used to make paper. Another quality of asbestos is that it is very malleable. This means asbestos can be flexed into different shapes. Plog, 1971 identifies two main groups of asbestos, which are pyroxenes and amphiboles.

History of Asbestos

Asbestos dates back to prehistoric times. However, it wasn't until the Industrial Age that this mineral became popular, mostly because of the "too good to be true" properties it possesses. Let's not forget that asbestos also has good fire retardant properties. With that said, asbestos became very popular in other industries as well. Asbestos is a carcinogen and the primary cause of mesothelioma. With all its popularity amongst industries, asbestos is still a danger to human health, causing such diseases as asbestosis, mesothelioma, and lung cancer.

Ancient debris that is approximately 700,000 years old has been identified by archeologists as containing asbestos. Mining asbestos rose in popularity in the 1800s. Asbestos makes a good insulator because it's resistant to heat. Imagine a machine that generates heat. What you need is a cover for the machine that provides protection from the heat to workers. Asbestos answers that call.

Uses of Asbestos

Lee, 1992 identifies asbestos under the following names: Actinolite, amosite, anthophyllite, chrysotile, crocidolite, and tremolite. We have already mentioned many of its uses including the automotive and construction industries and its properties making it a good insulator.

It appeared the Environmental Protection Agency was going to ban asbestos in 1990. This didn't happen and Burgess, 1995 explained that it continues to be used but in a smaller role than in its heyday.

Like I just explained, asbestos is still used but maybe not in as wide of use as a century ago. Asbestos is still out there and you can still find it on the internet. It appears that asbestos is commonly used in buildings that house businesses. Out where I work, there are some older buildings that have ceiling tiles that contain asbestos.

Back in the 1970s, my father was an asbestos worker when he lived in Washington State. Many people think of Washington State as large trees and mighty rivers, but not in southeastern Washington. In that area, the nuclear industry once thrived. My dad told me stories of working as an asbestos insulator in and around the old reactors that are long since shut down. For many summers in the late 1970s, he would work at these reactors changing the pipe insulation much of which contained asbestos. "A … common use of asbestos is in the manufacture of asbestos-cement pipe and panels" (Burgess, 1995). Dad would wear a heavy and hot suit and tear insulation from the many pipes. My dad assumed everything was safe because they had him breathing fresh air. They would spray him down with water before lunch to wash off any fibers that may have collected on his suit. I was born in Washington and I can only imagine how hot it was wearing those special suits! Also, just as a footnote to this story, my father has never been diagnosed with any asbestos-related disease.

"One of the principle uses of asbestos is in the manufacture of vehicle brake pads" (Burgess, 1995). I didn't know this but it does make sense. Brakes create friction and heat so why not use a material that can help! Sounds almost too good to be true.

I have seen other situations where asbestos containing material was simply covered with plastic. I guess, if the bad stuff is protected, it can't release the fibers that can hurt you. If the asbestos containing material is not disturbed, then the fibers cannot be released in the air to breathe.

Asbestos Health Hazards

The National Institute for Occupational Safety and Health (NIOSH) Pocket Guide to Chemical Hazards (U.S. Department of Health and Human Services, 1997) identifies many health hazards related to asbestos including asbestosis and lung cancer among others. Asbestosis is "A disease associated with chronic exposure to and inhalation of asbestos fibers. The disease makes breathing progressively more difficult and can lead to death" (Lee 1992). "Asbestos … [is a fiber that has] caused serious concern in the nonindustrial environment" (DiNardi, 1997). "Other health effects with asbestos include bronchogenic carcinoma, which is a malignancy of the lining of the lung's air passages" (Plog, 1971). Other negative health effects associated with asbestos include mesothelioma – malignancy of the lining of the chest cavity. This one is particularly nasty because there is also the possibility of a quick death if diagnosed with mesothelioma. Cancer of the stomach, colon, and rectum may also be caused by asbestos. This stuff is about as dangerous as you can find.

Asbestos Conclusion

EPA-600/M4-82-020 is the sample method number for asbestos. Again, asbestos sounds good, assuming you don't read any of the "fine print." But the dangers associated with the use of asbestos are real and should be considered before working with this mineral. The following is a table of important properties associated with asbestos (U.S. Department of Health and Human Services (Ed.), 1997).

Table 6: Properties of Asbestos

Name:	Asbestos
Formula	Hydrated silicates
CAS number	1332-21-4
DOT ID number	2212 (blue or brown asbestos) 2590 (white asbestos)
Emergency Response Guidebook number	171 (blue, brown, or white asbestos)
Other Names	Actinolite, Actinolite Asbestos, Amosite, Anthophyllite, Anthophyllite Asbestos, Chrysotile, Crocidolite, Tremolite, Tremolite Asbestos
Recommended Exposure Limit (REL)	$>$ 5 mm in length = 0.1 fiber/cm^3
Permissible Exposure Limit (PEL)	0.1 fiber/cm^3
Immediately Dangerous to Life or Health (IDLH)	Not determined
Carcinogen (Ca)	Yes
Routes of Entry (Inhale, Absorb, Ingest, Direct Contact with Eyes or Skin)	Inhale, Ingest, Direct Contact with Eyes or Skin
Target Organs	Respiratory System, eyes

"It is hard to find a chemical or a mineral that are good at so many things including a high tensile strength, flexibility, heat and chemical resistance, and favorable frictional

properties" (Plog, 1971). As opposed to working with asbestos, I think I'd rather spend my energy on finding an alternative and they are out there. There is insulation made of fiberglass for example. I'm all for living a good, healthy, long life and I don't think asbestos fits in my plans! Finally, let me add one more thing related to the story of my father and his work with asbestos back in the late 1970s. Every time he goes to see his doctor he fills out one or more of their questionnaires. When the doctor reads my dad's answers, he takes my dad to the x-ray room. Although all of the x-rays have been negative to date, it's still a bad thing to look forward to when visiting a doctor's office. In simple math terms, asbestos = nasty!

Trichloroethylene

What is Trichloroethylene?

Trichloroethylene, sometimes referred to as TCE, is not found naturally in the environment, it must be manufactured. In my work place, TCE is sometimes referred to as "trichlor" although I couldn't find any reference material that agreed. It must be local slang! TCE is a nonflammable liquid that has a "sweet" odor, which is sometimes compared to ether. TCE is typically used as either a solvent or a grease remover. I've used many different solvents and degreasers in my work around the house. If I'm using a solvent or degreaser (regardless of what it contains), I would be wearing safety glasses and using this compound in a shop that has ample ventilation with available fresh air. Further, absolutely no pets or kids allowed in the surrounding area! I don't want to take a chance on any accidents! The Toxic and Hazardous Industrial Chemical Safety Manual (1975) identifies the chemical formula of this chemical compound as $Cl–CH=C–Cl_2$.

Trichloroethylene is a "stable, low-boiling, colorless, heavy liquid with chloroform-like odor, miscible with common organic solvents; slightly [soluble] in water. Will not attack the

common metals, even in the presence of moisture. Slowly decomposes by light in the presence of moisture" (Manual, 1975).

History of Trichloroethylene

Trichloroethylene was originally sold in the early 1950s and was advertised as a degreaser. The pharmaceutical industry initially interested in TCE and even used it as an anesthetic. That is a rather scary statement. Over the past several decades, trichloroethylene has had several uses regarding humans. As previously stated, it was once used as an anesthetic. The medical community; however, had an interesting use for trichloroethylene; they used it as a disinfectant for the skin. As the years went by and the toxic effects became more known and understood, the acceptable and safe uses of trichloroethylene were beginning to shrink, especially regarding contact with humans.

Uses of Trichloroethylene

Currently, the main use for trichloroethylene is a process called vapor degreasing. In this process (typically used for cleaning of metal parts), solvents are converted to a vapor form and then used to clean surfaces. "Uses include metal degreasing, extraction solvent for oils, fats, waxes; organic synthesis, fumigant; medicine, cleaning and drying metal parts" (Manual, 1975, p. 536). McCoy 2005 indicates that vapor degreasing is mainly used for large scale "industrial degreasing operations." "Approximately 5% is used as an intermediate in the production of organic chemicals and pharmaceuticals" (Trichloroethylene Toxicity, 2007) There are also many other uses for trichloroethylene. Trichloroethylene is also used as a dry cleaning solvent. "For vapor degreasing, alternatives to TCE with similar performance characteristics are available. Alternatives can include the utilization of different solvents, switching to aqueous cleaners, adopting other mechanical cleaning techniques, or equipment substitution" (Fact Sheet on

Trichloroethylene (TCE), 2017). It sounds like there are plenty of trichloroethylene alternates available that could be explored.

Hazards Associated with Trichloroethylene

The National Institute for Occupational Safety and Health (NIOSH) Pocket Guide to Chemical Hazards identifies numerous health hazards related to trichloroethylene, including the "eyes, respiratory system, heart, liver, and central nervous system" (U.S. Department of Health and Human Services (Ed.), 1997). Trichloroethylene also has a large effect on the central nervous system. The inhalation of trichloroethylene would be a major concern as a route of entry. Specifically, from inhaling trichloroethylene, one could expect fatigue, headaches, confusion, and loss of sleep. I would think inhalation would be a big problem with trichloroethylene. It doesn't have an overpowering smell. Instead, it is rather sweet. Something like ammonia would catch a worker's attention rather quickly but not in this case. I can understand why there are specific effects such as a headache and confusion with a sweet "inviting" odor and not one that immediately knocks you off your feet.

There are other effects as well. Trichloroethylene may also have some effects on your kidneys, and skin. "Irritation of the nose and throat; increased respiratory rate, bronchitis, pulmonary edema, lack of appetite, nausea, vomiting, jaundice, slight swelling of liver, headache, dizziness, irritability, disturbance of sleep, incoordination, psychic disturbances, nystagmus (involuntary oscillations of the eye ball), paralysis, tremors, peripheral neuritis; precordial pain, cardiac arrhythmias, arrest, convulsions; retrobulbar neuritis; disturbances of color vision, [and] optic atrophy" (Toxic and Hazardous Industrial Chemicals Safety Manual for Handling and Disposal with Toxicity and Hazard, 1975).

Trichloroethylene also carries a cancer risk from exposure. "The cancer epidemiology for trichloroethylene has grown in recent years with several large, well-designed studies being published. A recent analysis of available epidemiological studies reports trichloroethylene exposure to be associated with several types of cancers in humans, especially kidney, liver, cervix, and lymphatic system. Consistency across epidemiological studies is strongest for an association between trichloroethylene exposure and kidney cancer." (Trichloroethylene, 1992)

Trichloroethylene Conclusion

NIOSH 1022 is the sample method number for trichloroethylene. Trichloroethylene is mostly used as a solvent and is found in degreasing agents. Trichloroethylene has been linked to a host of negative health hazards including cancer, respiratory, heart, liver, and central nervous system.

Below is a table of important properties associated with trichloroethylene (U.S. Department of Health and Human Services (Ed.), 1997).

Table 7: Properties of Trichloroethylene

Name:	Trichloroethylene
Formula	$Cl–CH=C–Cl_2$
CAS number	79-01-6
DOT ID number	1710
Emergency Response Guidebook number	160
Other Names	Ethylene trichloride, TCE, Trichloroethene, Trilene
Immediately Dangerous to Life or Health	1000 ppm

(IDLH)	
Permissible Exposure Limit (PEL)	100 ppm
Carcinogen (Ca)	Yes
Routes of Entry (Inhale, Absorb, Ingest, Direct Contact with Eyes or Skin)	Inhale, Absorb, Ingest, Direct Contact with Eyes or Skin
Target Organs	Eyes, skin, respiratory system, heart, liver, central nervous system

Beryllium

What is Beryllium?

Beryllium, with the chemical Be, is a grayish metal that is brittle at room temperature. Plog states, "[Beryllium is a] light weight gray metal. The metal, low-fired oxides soluble salts, and some alloys are toxic by inhalation" (Plog, 1971)

Beryllium, together with magnesium, calcium, strontium, barium, and radium, form the alkaline earth metals. Beryllium also has some interesting physical properties. For example, when beryllium has a chance to react with water, it will form an oxide. Another physical property example is the high thermal conductivity of beryllium. High thermal conductivity is a measure of how well a material will conduct electricity. Beryllium also maintains both a high melting point and a high boiling point. I found beryllium to be both ductile (very pliable) and very malleable (it can be hammered into different shapes without losing its strength). Speaking of strong, beryllium is a strong metal but also very light in weight at the same time. It will not corrode or rust over time, and it typically has a sweet taste but is extremely toxic.

Beryllium can be found naturally in the earth's crust in a very low percentage; however, it is not found in the earth's crust in its basic form. Beryllium is found in combination with other elements including volcanic rocks.

History of Beryllium

As stated previously, beryllium is not found in its basic form but rather in combination with other elements. For example, there exists a mineral called beryl. This mineral contains various elements including aluminum, silicates, as well as beryllium. This mineral (beryl) was used many centuries ago in Egypt.

Beryllium (the element) was discovered in the late 1700s by Nicholas Louis Vauquelin. Vauquelin, who was French, was a man of many talents as he was both a chemist and a pharmacist. The discovery of neutrons, by British physicist James Chadwick back in 1932, was helped along by beryllium by bombarding beryllium with alpha particles. Beryllium metal became widely available for commercial use in the late 1950s and was used (as an alloy) to harden copper and make it stronger.

Of the beryllium used in the world today, it is mined in the United States and Russia. Most; however, (about 67%) is mined in Utah.

Uses of Beryllium

Typically, when beryllium is used, it is used as an alloy to improve the strength of other elements. Iron, aluminum, nickel, and copper are the elements that beryllium is mainly an alloy. "Beryllium, probably the most toxic alloying metal, is added to copper and warrants close control during welding and brazing operations" (Burgess, 1995). "Beryllium is used industrially in three forms: as a pure metal, as beryllium oxide, and most commonly, as an alloy with copper, aluminum, magnesium, or nickel" (Beryllium, n.d.).

I have previously mentioned beryllium's excellent thermal conductivity property. As a quick reminder, this is a measure of how well a material conducts electricity. I also found that beryllium is a very popular metal in the aerospace industry because it is a very strong material. All added together, these properties make beryllium very popular in many additional industries including making satellites, building missiles, and aircraft and spacecraft parts. In fact, some rockets are fitted with rocket nozzles made of beryllium.

Around the 1999-2000 timeframe, a Formula One racing team used a race car that contained an engine with many parts that were made of beryllium. That brilliant idea didn't last very long though. Some of the competitor race teams were not very happy to be working around beryllium even though it was a different team, so they complained making reference to its toxic properties.

Beryllium also had some uses specifically for the United States military. At one time, the United States military used beryllium to make brake systems in aircraft. Beryllium; however, has run its course and is no longer used by the military because of the health hazards associated with the metal.

Hazards Associated with Beryllium

I wanted to provide a current number of American workers whose jobs typically involve contact with beryllium. I didn't find a current number, but I did come close. "According to the National Center for Biotechnology Information (NCBI), the estimated number of workers in the United States exposed to beryllium is 134,000" (Managing Health Effects of Beryllium Exposure, n.d.). Going back a few years in history, I found that there were approximately 800,000 workers in the United States exposed to beryllium in the 1970s timeframe.

A big hazard from exposure to beryllium is a disease called berylliosis, also called chronic beryllium disease. "Inhaling or contacting beryllium can cause an immune response that results in an individual becoming sensitized to beryllium. Individuals with beryllium sensitization are at risk for developing a debilitating disease of the lungs called chronic beryllium disease … if they inhale airborne beryllium after becoming sensitized" (Beryllium, n.d.).

Although there is currently no cure for chronic beryllium disease the symptoms; however, can be treated. This disease is caused by inhaling dust or fumes from the use of beryllium. Sounds pretty easy! What happens to cause berylliosis is this; dust and/or fumes are inhaled into the lungs. Over time, the dust /fumes will begin to irritate the lining of the lungs. After this happens, nodules in the lungs will begin to form. From this point as time goes by, the lungs will slowly begin to lose their ability to absorb oxygen. As previously stated, there is no cure. Since this disease cannot be cured, patients with the disease can always be monitored. Medications can be provided to address the symptoms.

Because the use beryllium may mean the creation of dust, the control of the dust created is essential. Because it only takes a very small amount of inhaled beryllium for the associated problems to begin to churn, the faster the controls are put in place, the better. If chronic beryllium disease wasn't bad enough, the breathing of beryllium dust or fumes over a period of time might lead to a disease called berylliosis (discussed later). Unfortunately, it doesn't matter whether you breathe a large amount of beryllium dust or fumes during a short period of time or a small amount during a longer period of time, the results may be the same.

Beryllium may also be found in coal slag. The coal slag is sometimes used in abrasive blasting. Typically, abrasive blasting is used to remove dried paint from metal surfaces. If there is an abrasive blasting operation going on, then any beryllium contained in the coal slag can be

released into the air. If there are unprotected workers in the nearby area, they could then be potentially exposed.

Beryllium Conclusion

How NIOSH 7300 OSHA ID 125G is the Sample Method Number for beryllium. How do I politely say this, after reading up about beryllium, I can say that working with beryllium is nasty business. On paper, beryllium sounds good as it has many good qualities and physical properties. But the list of possible things that can go wrong with beryllium is just as long if not longer. If you use the many available types of safety controls such as engineering, administrative controls, or PPE make sure you know what you are doing.

This element takes no prisoners, and it doesn't take a large quantity of beryllium or a long period of exposure time before the damage starts. Once the damage starts, it cannot be reversed! If you use the engineering and administrative controls (along with personal protective equipment), take the time to make sure the medical monitoring is sound and that you are safe. If you have to handle beryllium, it must be handled in such a way to reduce or (hopefully) eliminate exposure. The improper handling of this hazardous material could lead to the release of beryllium dust.

The following is a table of some of the important properties associated with beryllium (U.S. Department of Health and Human Services (Ed.), 1997).

Table 8: Properties of Beryllium

Name:	Beryllium
Symbol	Be
CAS number	7440-41-7
DOT ID number	1566 (compounds)

	1567 (powder)
Emergency Response Guidebook number	154 (compounds) 134 (powder)
Other Names	Synonyms vary depending on the Beryllium compound
Permissible Exposure Limit (PEL)	0.002 mg/m^3 TWA 0.005 mg/m^3 Ceiling 0.025 mg/m^3 Peak (for 30 minutes)
Immediately Dangerous to Life or Health (IDLH)	4 mg/m^3
Carcinogen (Ca)	Yes (lung cancer)
Routes of Entry (Inhale, Absorb, Ingest, Direct Contact with Eyes or Skin)	Inhale, Direct Contact with Eyes or Skin
Target Organs	Respiratory System, eyes, skin

Silica

What is Silica?

Silica is a mineral that can be easily found in many materials. Sometimes silica is referred to as quartz, and it can be found in many places and many things including concrete, soil, granite, and sand. Silica doesn't standout much because it is a colorless material, white, chemical compound. "Silica is made of the most common elements on earth, silicon (Si) and oxygen (O_2). It's also the most abundant compound in the earth's crust, where it makes up 59% of the total composition" (Group, 2016).

Silica is “mostly” harmless. There are also many other places where silica is hiding including glass, food, plants, medicines, toothpaste, and cosmetics. I have a bottle of medicine on my dresser, and inside it, there is a pack of silica to absorb the moisture in the bottle. I've made many trips to the beach in the past few years. The sand at the beach contains silica.

History of Silica

Henry Hunter was a man who mined and processed sand in West Virginia in the late 1800s. Although most miners were looking for gold or silver, Hunter was not. I guess he still qualifies as a “pioneer.” His process was so good (and the silica samples were equally as good) that one of his samples ended up in the Chicago World’s Fair. His sample eventually won a blue ribbon for purity! About this time, the silica industry was taking off in the United States. Silica plants began sprouting up all over the place looking for silica to mine. The silica would eventually be used in multiple products including glass manufacturing. By the way, a man named Samuel S. Woods from Pennsylvania built a production plant that would later become the Pennsylvania Glass Sand Corporation. Since there were many uses for silica and there was a large supply ready to be mined, many new companies began appearing.

In the United States, the hazards associated with crystalline silica were first identified in the 1930s. After the Occupational Safety and Health Act (1970) became law, exposure limits were established. As previously mentioned, these limits were not effective in protecting workers from the hazards of breathing silica dust. Since that time, there have also been some new ways to be exposed to silica dust including hydraulic fracturing and the manufacturing of countertops.

With worker exposure remaining a problem, the final rule was proposed in September 2013. OSHA, in support of this final rule, gathered much input and help public hearings. The

comments obtained allowed OSHA to make many changes while still protecting the health of the workers themselves.

Uses of Silica

In the last section, I wrote that silica is found in many every-day places and materials including soil, sand, concrete, masonry, rock, medicines, cosmetics, granite, and even in toothpaste. Basically, silica can be found most anywhere. Well, with that said, silica has as many uses as it does sources. “It’s also the most abundant compound in the earth’s crust, where it makes up 59% of the total composition. Silica is used everywhere, from industrial applications to the food and beverage industry” (Group, 2016).

Before I began this project, I didn’t realize that silica can be found in the body and can also be found in many common foods I have around the house. From poking around the internet, I found the following foods that contain some level of silica including apples, bananas, pumpkins, honey, mangoes, oranges, carrots, cabbage, peanuts, cucumbers, onions, cereals, grains, oats, green beans, brown rice, and almonds. Comparing plant foods against animal foods, it looks like plant foods are the winner here and contain more silica. When the body absorbs silica, it will only absorb a small amount and then expel the remainder.

After silica is taken up by the human body, it is found mainly in the following locations: heart, kidneys, tendons, liver, and bones. For the human body to be able to use silica, it must be in a form where it can be consumed. This form is called orthosilicic acid. From my research, it was unclear what part silica plays in human health. Most of my readings indicated much more research is needed in this area. The presence of orthosilicic acid in the human body is a good thing. Orthosilicic acid aids in keeping bones strong and making them less brittle. Silica is also a part of a healthy immune system.

This is not the end of the positive effects list for silica. Silica also acts like an antioxidant in your body when combined with water. I've listened to many news programs on the television about antioxidants. But I was never really sure exactly what antioxidants did. What it comes down to is this. The higher the antioxidants in your body, the more likely you are to be healthy. According to Benefits of Antioxidants, "increasing your antioxidant intake can help provide added protection for the body against several problems, including heart problems, eye problems, memory problems, mood disorders, and immune system problems" (Benefits of Antioxidants, n.d.)

Just like there is good cholesterol and bad cholesterol, there is good silica and bad silica. Silica hydrate is the good kind and results from silica combining with water molecules. When silica hydrate is taken as a supplement, it hydrates cells and acts as a powerful antioxidant.

On the other hand, crystalline silica is not so good for you and has been identified as a carcinogen. "The seriousness of the health hazards associated with silica exposure is demonstrated by the fatalities and disabling illnesses that continue to occur in sandblasters and rockdrillers" (Crystalline Silica Exposure Health Hazard Information, n.d.).More discussion about crystalline silica and the harmful effects of the dust is included later. There are many industries where dust from crystalline silica is a potential hazard. The following is a list of the industries of where this dust from crystalline silica can be located; "construction, glass products, pottery products, structural clay products, concrete products, foundries, dental laboratories, paintings and coatings, jewelry production, factory products, ready-mix concrete, cut stone and stone products, refractory installation and repair, railroad track maintenance, hydraulic fracturing for gas and oil, and abrasive blasting" (Safety and Health Topics: Silica, Crystalline, n.d.).

Abrasive blasting, which creates much dust, seems to be the main culprit regarding the creation of dust. My father, Gary Corrigan, in his early career was a Quality Control (QC) Inspector at many large-scale construction sites around the country. As a QC Inspector, he performed most of his inspection tasks out of the office area and in the field. One of the big tasks he had was inspecting freshly blasted metal to verify that rust and other defects had been removed by the abrasive blasting process.

He told me that he had spent 10-12 years in the field performing this function and in all that time he was working in an extremely dusty environment. This was back in the early 1980s and respirators were not required at least where he worked they were not required. He told me stories where he often had to shake the dust off his clothing before he could get in his car and drive home at nights after his shift was over. He would get extremely sore throats often and miss work as a result.

Eventually, he got smart and started wearing dust masks on his own. He said that the other employees would look at him strangely because they were not wearing dust masks but he ultimately did what he had to do. Besides the dangerous environment he worked in, what stood out was that there were no requirements for any level of respiratory protection and that there were other crafts working in the proximity that didn't see anything as a problem. The dust masks that he wore were available but not easily available. I sure hope all of them are still alive and healthy. I do know that almost every time my father goes for a work physical, he gets sent to get a full chest x-ray.

Besides abrasive blasting, crystalline silica dust can also come from many other industries. This includes the jewelry industry, etching glass, manufacturing of China, abrasive

cleaners from around the house, and still others. The point here is that crystalline silica or the dust associated with crystalline silica can come from many different sources.

Hazards Associated with Silica

"Silica used in the food and beverage industry is safe to take orally. However, that doesn't mean that silica is always safe for humans. Silica actually comes in many forms — some safe, some not" (Group, 2016). From my research, I found two basic forms of silica.

First, when mixed with water, silica forms silica hydrate. As discussed earlier, silica hydrate acts as an antioxidant when taken as a food supplement.

Second, crystalline silica can be quite harmful. In the previous section, I discussed several uses of silica, which is where the problems begin. Many of the individual uses of silica include construction, glass products, pottery products, structural clay products, concrete products, paintings and coatings, jewelry production, concrete, and cut stone and stone products. Most of these industries include processes that require the silica to be cut or ground upon. Well, the end result of the cutting or grinding operations could be releasing dust into the air that contains crystalline silica particles.

Breathing the silica dust is the primary route of entry into the body. These particles would be very small and cannot be seen by the naked eye. The NIOSH Pocket Guide to Chemical Hazards (1997) indicates that crystalline silica causes cancer. "Recognizing that very small, respirable silica particles are hazardous, the Occupational Safety and Health Administration (OSHA) regulation 29 CFR 1926.1153 requires construction employers to keep worker exposures at or below a Permissible Exposure Level (PEL) of 50 $\mu g/m^3$" (Why is Silica Hazardous?, n.d.). "OSHA estimates that over 100,000 workers in general industry and maritime are exposed to silica levels that exceed the new permissible exposure limit (PEL)" (OSHA's

Crystalline Silica Rule: General Industry and Maritime, 2016). From data contained in OSHA Publication 3682 (OSHA's Crystalline Silica Rule: General Industry and Maritime, 2016), I have created the table below which identifies the various industries that use silica. In this table, I have included the number of workers exposed to silica dust, the number of workers exposed to silica dust above the PEL, and the percentage of workers exposed to silica dust above the PEL.

Table 9: Worker Exposure to Silica Dust (OSHA's Crystalline Silica Rule: General Industry and Maritime, 2016).

Industry	**Workers Currently Exposed**	**Workers Currently Exposed Above The PEL**	**Percentage Of Workers Exposed Above The PEL**
Asphalt Roofing Materials	3,158	1,410	44.6%
Concrete Products	32,981	9,391	28.5%
Cut Stone	9,429	5,243	55.6%
Dental Laboratories	31,105	864	2.78%
Foundries	34,591	12,173	35.2%
Jewelry	6,772	2,434	35.9%
Porcelain Enameling	4,113	1,654	40.2%
Pottery	6,269	2,496	39.8%
Railroads	16,895	5,340	31.6%
Ready-Mix Concrete	27,123	19,941	73.5%
Shipyards	3,038	2,228	73.3%

Structural Clay Products	7,893	3,198	40.5%
Support Activities for Oil and Gas Operations	16,960	11,207	66.1%

Controlling Silica

Crystalline silica is a problem. In the performance of their jobs, many millions of workers are routinely exposed to the dust created from such operations including drilling, grinding, or cutting. Let's not forget the thousands of other workers who are also exposed to crystalline silica from brick making hydraulic fracturing (also known as fracking). Because crystalline silica causes cancer and is associated with health hazards in small amounts, exposure to this type of silica should be carefully controlled and monitored. Exposure to crystalline silica should be eliminated or substituted whenever possible. Removing the hazard from the work area or engineering controls, such as the use of exhaust ventilation, would be the best way to minimize or even eliminate worker exposure to crystalline silica.

If exposure to crystalline silica cannot be reduced or eliminated, administrative controls would be the next best option. For example, a procedure or company policy could be developed requiring works to wear personal protective clothing and a respirator when working around the silica dust. Other methods of dust control include a vacuum system or the use of water. The procedure or policy could also require (not suggest) workers to change clothes prior to going home at the end of shift, or even limit exposure times.

"OSHA is issuing two standards to protect workers from exposure to respirable crystalline silica — one for general industry and maritime, and the other for construction — in order to allow employers to tailor solutions to the specific conditions in their workplaces" (OSHA's Crystalline Silica Rule: General Industry and Maritime, 2016).

Silica Conclusion

NIOSH 7500 is the sample method number for silica. Of the minerals and chemicals researched for this project, silica is getting much attention in the "OSHA" world (I could go on and on about silica and its hazards). Just breathing a small amount can be hazardous to the worker's health and over a period of time could even cause cancer. In the United States, worker exposure to harmful silica (crystalline silica) is a serious threat in many different industries. If possible, substitute another product for silica. Also, breathing crystalline silica dust can cause silicosis, which cannot be cured and could be fatal. Here, dust particles entering the lungs may reduce their ability to absorb oxygen.

There are alternatives to silica when sandblasting. One substitution is to blast using crushed nut shells. The use of nut shells will prepare the surface you are blasting but without the sand and the dust. One other alternate for sandblasting is to use saw dust. Yes, there is dust but not crystalline silica dust!

What is Silicosis?

Silicosis (sometimes called grinder's asthma) is a lung disease caused by inhalation of crystalline silica dust. This disease occurs when the inhaled dust, over a period of time, causes inflammation or scarring inside the lungs. While silicosis may not occur for many years after exposure (maybe 15–20 years), it is dependent on basically two factors. First, the amount of crystalline silica that is present in the dust you are breathing. Second, the length of time the

worker was exposed. A worker exposed to crystalline silica could expect to experience many different symptoms including shortness of breath, chest pain, or maybe even respiratory failure depending on the amount of crystalline silica breathed and the length of time of the exposure. None of these symptoms sound like a good time, and there is no cure for silicosis.

Regarding the PEL for silica, it was outdated, not very consistent, and it missed the mark when trying to protect the workers. Because of this, there is a new PEL for crystalline silica exposure. The PEL as a reminder is the maximum amount that a worker may be exposed to during an 8-hour shift.

If you work near crystalline silica, then be prepared to receive some training. Here, hazard communication training is required for workers who are routinely exposed to crystalline silica. Since creating dust is a strong possibility when working around crystalline silica, a respirator protection program is also required. There is also a National Emphasis Program, which was implemented by OSHA. This program is used primarily to identify, reduce, and eliminate hazards based on exposures to materials.

Below is a table of important properties associated with silica (U.S. Department of Health and Human Services (Ed.), 1997).

Table 10: Properties of Silica

Name:	Silica
Formula	SiO_2
CAS number	14808-60-7
Other Names	Quartz, Tridymite, Tripoli

Permissible Exposure Limit (PEL)	50 µg/m^3
Immediately Dangerous to Life or Health (IDLH)	50 mg/m^3 (quartz) 25 mg/m^3 (crystalline)
Carcinogen (Ca)	Yes
Routes of Entry (Inhale, Absorb, Ingest, Direct Contact with Eyes or Skin)	Inhale, Direct Contact with Eyes or Skin
Target Organs	Eyes, Respiratory System

Upcoming Silica Changes

Because of the many hazards that go along with silica dust (e.g., silicosis, kidney disease, chronic obstructive pulmonary disease, and cancer), OSHA has issued a "final rule" to limit exposure. This rule contains two parts. Part 1 is for construction and Part 2 is for general industry and maritime. OSHA is expecting a big payoff as a result of this final rule in the form of saving lives, preventing individual cases of diseases, and (of course) saving money.

There are several main requirements of this rule. These requirements include lowering the PEL to 50 µg/m^3, using engineering controls to control dust (and respirator use when these controls are not enough), an exposure control plan, an enhanced medical surveillance program, and assist small business in protecting workers.

The two standards took effect on June 23, 2016 with up to five years to comply. Yes, there is a compliance schedule. For construction, final rule compliance date was set at September 23, 2017 (Note: to conduct additional research, OSHA delayed compliance/enforcement). Also, individual employers will be provided educational pamphlets and guidance. For general industry

and maritime, June 23, 2018 is the date and for hydraulic fracturing, compliance is June 23, 2018 (excluding engineering controls - June 23, 2021).

Conclusion

People working with chemicals and minerals can work. However, some chemicals and minerals that are also hazardous need to be properly managed to get the job done safely. Many chemicals and minerals have health concerns up to and including cancer causing.

There are many different ways to protect workers and the environment including engineering controls, administrative controls, and personal protective equipment. While each of these methods can provide needed protection from hazards, the most important aspect here is knowledge.

Workers need to be made clearly aware of the hazards associated with certain chemicals and minerals. The more the workers know, the more questions they can ask. Staying safe from the effects of chemicals and minerals is more than reading a label. There is much information available to workers from various sources including various publications published from many credible organizations like Occupational Safety and Health Administration and the Centers for Disease Control and Prevention and Safety Data Sheets generated by the individual manufacturers who make the chemicals and materials. Workers have the right to know what hazards are associated with the materials they are working with.

With the advanced worker knowledge from these organizations and publications comes smarter and workers that are more involved in safety. In the end, I not only rely on my fellow coworkers to keep me safe, I also rely on myself to become educated and informed. Everyone working together will not only promote worker safety, it will also make sure that at the end of

the work day, I go home to my family in the same way I drove to work at the beginning of my last shift.

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